INVERSE CALCULATION OF AEROSOL FORCING

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ABSTRACT

Change in global mean surface temperature (GMST) is driven by total forcing, the major components of which are thought to be increased concentrations of greenhouse gases and aerosols. While greenhouse gas forcing is relatively well known, aerosol forcing remains quite uncertain, with central value (1750-2005) of -1.2 W m^{-2} [range -0.6 to -2.4 W m^{-2}, 5-95%; IPCC AR4, 2007; negative forcing denotes cooling influence]. Forward calculations of aerosol forcing are based on modeled aerosol loading and properties and/or from observed loadings of aerosols and correlations of aerosol loadings and cloud albedo. Alternatively aerosol forcing can be inferred by inverse calculations based on assumed climate sensitivity, measured change in GMST, and forcings other than by aerosols. Here I rely on recent empirical determination of Earth's equilibrium climate sensitivity (Schwartz, 2007) as the quotient of climate system time constant τ and effective heat capacity C. τ is determined from autocorrelation of GMST over 1880-2004 as 5 ± 1 yr (uncertainties are 1-sigma estimates). Effective heat capacity is determined from change in global ocean heat content with increasing GMST over 1955-2000, 14 ± 6 W yr m^{-2} K^{-1}, equivalent to 110 m of ocean water; other sinks raise the effective planetary heat capacity C to 17 ± 7 W yr m^{-2} K^{-1}. The resultant equilibrium climate sensitivity, 0.30 ± 0.14 K/(W m^{-2}), corresponds to an equilibrium temperature increase for doubled CO_2 of 1.1 ± 0.5 K, well lower than current IPCC estimates. The short time constant implies that GMST is in near equilibrium with applied forcings and hence that net climate forcing over the twentieth century can be obtained from the observed temperature increase over this period, 0.57 ± 0.08 K, as 1.9 ± 0.9 W m^{-2}. For radiative forcing by incremental greenhouse gases, 2.2 ± 0.3 W m^{-2}, other forcings over the twentieth century, mainly by incremental tropospheric aerosols, are inferred to be slight, -0.3 ± 1.0 W m^{-2}. While the central value of this estimate is quite small, the range encompasses both fairly substantial negative forcing as well as possible positive forcing. These considerations emphasize the need for improved forward calculations of aerosol forcing to constrain estimates of climate sensitivity and to permit evaluation of climate models from their skill in reproducing temperature change over the twentieth century.

Schwartz S. E. Heat capacity, time constant, and sensitivity of Earth's climate system. J. Geophys. Res. in press, 2007;. http://www.ecd.bnl.gov/steve/pubs/HeatCapacity.pdf